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Abstract

Nature-based solutions (NBS) have evolved as a vital tool for tackling water-related issues and challenges around the world. It is increasingly recognized that co-creation, co-design and co-implementation enhance longevity of NBS by matching NBS to local contexts. We assume that co-creation is of central importance for NBS, but also wider societal and environmental contexts matter when thinking of longevity of NBS. To understand NBS, we build on the concept of fit between NBS as environmental and governance interventions and local contexts where the NBS are implemented. The objective of the present paper is to analyze four cases on water-related NBS in Global South from the perspective of fit. These case studies address the adaptive co-management of river ecosystem in Brazil, construction of rainwater harvesting ponds in Pakistan-administrated region of Jammu & Kashmir, watershed restoration projects in Piura (Peru), the rehabilitation of ponds and forests on Carriacou Island, Grenada. Through an inductive cross-case analysis, we identify seven recommendations essential for achieving fit between NBS and local contexts. Our paper urges future research to deepen theoretical understanding of fit dynamics, develop context-sensitive evaluation frameworks, and explore how NBS can catalyze long-term transformations toward sustainable and just water governance.

Keywords: Social-ecological fit; Nature-based solutions; Global South; Water

1. Introduction

Water-related challenges are likely to amplify with climate change including droughts, floods, challenges regarding availability and quality of water and water related hazards (Abera *et al.*, 2025; Biswas *et al.*, 2025). Nature-based Solutions (NBS) are a promising approach to address water related challenges (Oral *et al.*, 2020). NBS have emerged as a primary strategy to address pressing environmental challenges such as biodiversity loss, water scarcity, climate resilience, and sustainable development (Cohen-Shacham *et al.*, 2016, 2019; Nesshöver *et al.*, 2017). The International Union for Conservation of Nature (IUCN) defines NBS as "actions to protect, sustainably manage and restore natural and modified ecosystems in ways that address societal challenges effectively and adaptively, to provide both human well-being and biodiversity benefits" (Cohen-Shacham *et al.*, 2016; IUCN, 2020). In recent years, NBS have been extensively adopted in international policy frameworks, including the EU Green Deal, the UN Decade on Ecosystem Restoration, and the Convention on Biological Diversity (Raymond *et al.*, 2017; Frantzeskaki, 2019; Frantzeskaki *et al.*, 2019; Seddon *et al.*, 2020, 2021; Seddon, 2022) and have moved from a peripheral conservation idea (Pauleit *et al.*, 2021) into the center of global water, climate and urban policy. Moreover, national governments, NGOs, and development organizations invest in NBS since they are climate smart, cost-effective, and multipurpose alternatives as compared to traditional grey infrastructure. However, many projects often run into the well-documented implementation gaps between high-level policy adoption and on-the-ground delivery (Martin *et al.*, 2025).

Despite their increasing popularity, NBS implementation across diverse ecological and socio-political contexts has produced mixed outcomes (Kabisch *et al.*, 2016) and include trade-offs instead of being win-win panacea for sustainability challenges (Seddon, 2022; Stijnen, Frantzeskaki & Wijsman, 2024). Although certain initiatives produce transformative outcomes (Kauark-Fontes, Marchetti and Salbitano, 2023), others are unsuccessful, fail to scale, or result in undesirable consequences (Carmen *et al.*, 2024; O'Leary *et al.*, 2024; Martin *et al.*, 2025). Especially in regions of Global South, governments continue to be biased towards traditional grey infrastructure approaches over NBS due to the lack of evidence on their cost-effectiveness and flawed designs, poor funding mechanisms to sustain indigenous water management system, and unsolved constraints embedded in policy and finance and not in ecology (Wolff *et al.*, 2022; Barbarwar, Gupta and Parmar, 2023; Woroniecki *et al.*, 2023; Abera *et al.*, 2025; Mirsafa, Castaldo and de Oliveira, 2025). It may be argued that the missing analytical lens in much of this evidence is the idea of a 'multidimensional fit' indicating towards the mismatches between NBS design and implementation, and local contexts including aspects of governance, knowledge, ecological conditions, economy, and technological realities. Drawing on the concept of fit (Young, 2002), we consider that matching NBS with local contexts enables not only implementation of NBS, but also their

sustenance over time, enhanced justice and acceptability, and also ecological functionality (Box 1).

Box 1. Analytical approach: Multidimensional and dynamic fit between NBS and local contexts.

Multidimensional and dynamic fit

To empirically explore the relevance of the *fit* in determining the outcomes of NBS for water governance, we draw on Young's (2002) foundational work and subsequent refinements in adaptive governance and socio-ecological systems theory. The concept of fit refers to the congruence, alignment, or compatibility between the characteristics of social institutions (rules, regimes, governance systems) and the properties of the ecosystems they are intended to manage (Young, 2002). This original concept of fit is thus about relationships between institutions (policy) and environment.

While Young's concept provides the starting point for our analysis, we do not understand fit as a simple correspondence between institutions as solutions and ecosystems as problems. Such a separation becomes particularly difficult in the case of NBS, which are simultaneously ecological interventions and socially organised practices. Previous extensions of institutional fit have similarly questioned a strict distinction between institutions and ecosystems, emphasizing how existing institutions, local practices and actors may constitute both elements of the problem and resources for its resolution (Hiedanpää, 2013). Building on this relational understanding, we conceptualise fit as multidimensional: it emerges through interactions among ecological conditions, knowledge systems, governance arrangements, economic incentives, technologies, and socially embedded practices.

This perspective also makes fit dynamic rather than predetermined. NBS modify, restore, protect, manage, or create ecosystems (IUCN, 2020; Sowińska-Świerkosz and García, 2022), but their implementation simultaneously encounters and may reshape existing institutions, practices, and societal expectations. Consequently, the question is not simply whether institutions fit ecosystems, or whether ecological interventions fit society, but how NBS become aligned with, and potentially transform, the socio-political and ecological contexts in which they operate.

On this basis, we operationalise multidimensional fit through five interrelated contextual dimensions: knowledge systems, governance structures, environmental conditions, economic dynamics, and technological appropriateness. These dimensions represent key aspects of the pre-existing context with which an NBS interacts during its design, implementation, and continuation. Rather than treating them as independent categories, we use them as analytical entry points for examining how different forms of alignment and misalignment combine to shape the longer-term viability of NBS.

Rather than treating fit as a fixed correspondence established at the moment of NBS implementation, we conceptualize fit as a dynamic relationship between NBS and the contexts in which they are embedded. Importantly, the effectiveness of NBS can be contextualized through the notion of multidimensional fit, which emphasizes the alignment of interventions with interconnected social, ecological, technological, financial, and governance systems operating across multiple scales (Tzoulas *et al.*, 2021). These dimensions form the basis for evaluating each case study and allow for both within-case and cross-case comparison of fits and misfits. The concept of fit refers to the extent to which an intervention, like NBS, integrates with the social, ecological, and institutional circumstances in which it is embedded and implemented (Young, 2002; Galaz *et al.*, 2008; Pahl-Wostl *et al.*, 2023) (Table 1; Annex 1).

Table 1. Five contextual dimensions of fit.

Dimension	Question of Fit	Misfit Example	Fit Example	Example references
Knowledge Systems	Compatibility / integration of NBS with existing (local) knowledge	Ignoring traditional and community knowledge	Co-production of knowledge	(Cash *et al.*, 2006; Norström *et al.*, 2020)
Governance Structures	Synchronization of NBS with existing institutions, authority, and coordination	Rigid, top-down management, linear	Polycentric, adaptive governance, organic/complex, inclusive	(Galaz *et al.*, 2008; Ostrom, 2009).
Environmental Conditions	Ecological suitability of NBS	Poor site selection or hydrological mismatch	Landscape-integrated, climate-resilient design	(Holling, 2001; Pahl-Wostl, 2015).

Economic Dynamics	Viability of NBS with existing livelihoods, incentives, and resources	High-cost, low-livelihood compatibility, centralized profits	Low-cost, community-benefiting interventions, distributed profits, inclusiveness and ethics, self-management models	(Biggs, Schlüter and Schoon, 2015; Primmer *et al.*, 2015).
Technological appropriateness	Local accessibility, maintenance, and adaptation of NBS' tools and techniques	Complex tech requiring external maintenance, economic advantages, market potential	Simple, replicable, community-driven tools, social ambition, social inclusion, community-driven	(van der Hel, 2016).

In the present paper, we consider fit as the relationship between NBS and the local contexts into which they are introduced. NBS do not enter institutionally or ecologically empty spaces; rather, they encounter pre-existing socio-ecological situations shaped by institutions, practices, knowledge systems, technologies, economic arrangements, and environmental conditions. Because NBS are simultaneously environmental and governance interventions (Sarkki *et al.*, 2024), their effectiveness depends partly on how they interact with these existing contextual conditions. Misfit may therefore arise when an NBS conflicts with, overlooks or fails to adapt to important features of the context in which it is implemented.

Concepts of NBS and fit have not yet been coupled to existing scientific literature. This is a conceptual gap the present paper addresses. Enhancing the social-ecological fit of NBS can respond to a persistent "context gap" in sustainability interventions (Nesshöver *et al.*, 2017), and as such contributes to sustaining NBS also under changing future conditions. The context gap refers to the disconnect between "idealized" design of NBS, and the often-messy local circumstances where NBS is implemented. We assume that NBS interventions are more likely to sustain in time and succeed in delivering sustainable ecological and social co-benefits when they are aligned (fit) with local contexts. Local contexts include knowledge systems, governance structures, environmental dynamics, and community priorities. Conversely, misfit between NBS and local circumstances results in decline of NBS, lost opportunities, limited impact, or unintended consequences. By enhancing fit to address the context gap, may require place-based tailoring that improves effectiveness of NBS (Mirsafa,

Castaldo and de Oliveira, 2025), overcoming governance and implementation barriers (Kauark-Fontes, Marchetti and Salbitano, 2023), and addressing equity and trade-offs (Egerer *et al.*, 2024).

This study applies a multidimensional fit framework to four cases of NBS for water governance in the Global South – particularly in Brazil, Pakistan, Peru, and Carriacou (Grenada). These cases cover a wide range of ecological regions including the Cerrado tropical savanna, Himalayan foothills, Andean highlands, and Caribbean Island. Governance systems include community-led, state-supported, and donor-funded ones, and the type of interventions include riverbank restoration, rainwater harvesting, water sowing, pond rehabilitation.

Global South NBS, addressing the water related problems, face partly different challenges than those in Global North. This is related to the issue of NBS tends to be conceptualized in the Global north and relocated or being adapted in Global South (McPhearson *et al.*, 2025), despite Global south experience a fastest urban growth, high exposure to climate hazards, informal settlement expansion, untreated and degraded water systems, and governance fragmentations (Abera *et al.*, 2025). Differences link for example to high levels of water and solid waste pollution and large quantities of untreated wastewater, severe loss of permeable spaces for rainwater infiltration and groundwater recharge, and hydrological changes (Sarabi *et al.*, 2020; Mguni *et al.*, 2022). Besides, colonial legacies and rapid urbanization have led to infrastructure deficit to tackle water issues (Pauleit *et al.*, 2021). The lack of monitoring data compromises solutions to water linked challenges in Global South (Collier *et al.*, 2023). This may require adopting an integrated, context specific and data-driven approach in planning and implementation of NBS embedded in local challenges, needs and priorities and special attention to keeping metrics for biodiversity index, hydro-meteorological hazards, ecosystem services, and economic evaluation of NBS interventions (Mirsafa, Castaldo and de Oliveira, 2025). These issues along with low institutional capacity to govern water hinders NBS in the Global South (Nassary *et al.*, 2022).

NBS need to fit the contexts where they are implemented. In Global South, identified features of context include need for knowledge about the watershed dynamics; understanding of building and infrastructure context, understanding of ecological and biodiversity context, understanding complexities of NBS implementation, enhancing community engagement, introduction of appropriate funding mechanisms and valuation of ecosystem services (Abera *et al.*, 2025). Further focus must be put on the mechanism that facilitate a participatory approach and multi-stakeholder engagement in the planning and implementation process leading to higher social acceptability of NBS and the need to ensure that NBS design go beyond environmental benefits and provide wide range of socio-economic benefits i.e.

livelihood opportunities for local communities (Mirsafa, Castaldo and de Oliveira, 2025). Our multidimensional fit approach allows for the identification of cross-cutting enablers of fit and structural barriers to implementation, thereby providing practical insights into how future NBS initiatives can be better tailored to local realities.

The objective of the present paper is to analyze the four cases on water-related NBS from the perspective of multidimensional fit. We examine how environmental and governance interventions introduced through NBS fit their local contexts, rather than how institutions fit ecosystems. This helps to understand what attributes contribute and challenge the continuity of NBS in the future.

Results

Four case studies

We contribute to the growing literature on water-related NBS in Global South by examining four case studies. By analyzing Brazil (ARIS Dorothy Stang), Peru (Water Sowing & Harvesting), Carriacou (Forest and Water Restoration), and Pakistan (Rainwater Harvesting Ponds) with the concept of fit, we provide a nuanced understanding of how *fit* shapes the success or limitations of NBS in diverse Global South contexts. Four case studies were purposively selected based on the geographic and ecological diversity, difference of the governance regimes, and their shared reliance on NBS for addressing water-related challenges. These cases reflect a diversity of ecosystems (mountains, islands, tropical forests), governance systems (state-led, donor-supported, community-initiated), and scales (household to regional). Together, they provide a rich empirical basis for understanding the dynamics of fit and misfit in NBS implementation (Table 2).

Table 2. Overview of the four case studies (See Annex 2 for details).

	Case 1	**Case 2**	**Case 3**	**Case 4**
Case country	**Brazil**	**Carriacou (Grenada)**	**Pakistan**	**Peru**
Local region	Brazilian Cerrado	Caribbean	Pakistan-administered Kashmir	Piura region
Problems addressed	Erosion, flooding, recurring flash floods in urban	Chronic water scarcity / drought, lack of potable groundwater,	Seasonal water scarcity, declining groundwater	Water insecurity, seasonal variability, impacts on local production

	areas, riparian degradation, water scarcity and altered river flows associated with deforestation and land-use change, contributing to seasonal hydrological instability and flood vulnerability.	seasonal water insecurity (4-6 month dry season), ecosystem degradation (deforestation, soil erosion), governance challenges (water access inequality: undersized desalination plant & public water pipe distribution network incomplete, cattle, sheep & goat grazing conflicts	levels and rapid monsoon runoff in mountainous terrain, alongside recurrent flood and erosion risks during periods of intense rainfall.	systems, weak upstream–downstream governance, and limited financing for NBS
Primary objectives of the NBS	To improve water regulation, biodiversity, and social inclusion	To improve water availability, ecosystem restoration, and local climate resilience	To enhance water detention and retention by capturing seasonal rainfall and runoff in ponds, thereby supporting groundwater recharge, reducing rapid surface runoff, and improving water availability during dry periods.	Improving the adaptive capacity of rural populations and farming communities to the effects of climate change.
NBS as environmental intervention	Leapfrogging approach to build green infrastructure (rain garden) and other community-based initiatives for water management.	Forest and mangrove restoration, pond rehabilitation, and swale-based water retention systems	Construction of decentralized rainwater harvesting ponds	Implementing soil infiltration systems through water reservoirs or ponds as green infrastructure for rainwater harvesting, and reforestation
NBS as governance intervention	Community-driven ecological rehabilitation.	NGO-led, community-based initiative with	A grassroots initiative led by a local community member	A large-scale watershed management strategy. Hybrid

		limited state involvement		governance: state-supported, NGO-facilitated, and community-implemented watershed management

Identifying misfit across the cases

The case study reports identified set of problems that can hinder NBS implementation for long-term success. These problems were inductively clustered under 24 intermediate clusters and 8 general categories. The general categories are formulated in Table 3 as signs of misfits challenging long term viability of the NBS. The signs of misfit link to findings from the case studies under broader categories of 1) social justice challenges, 2) Lack of participation opportunities for local actors, 3) Poor connectivity between science and policy, 4) Incoherent policies, 5) Inefficient governance, 6) Poor water management, 7) Limited funding for community-based NBS, and 8) Low community capacities.

Table 3. Signs of misfits based on inductive analysis of the case study reports.

Insights from cases	Intermediate clusters	General categories
Lack of efficient network of public service water trucks, funded by the local administration, to provide water to needy poor families unable to pay the high costs of a private water truck (Carriacou).	Lack of financial support for local (poor) families to gain access to water	**Social justice challenges**
Legally obligated establishment of water mine project necessitates relocation of some families (Brazil)	Relocation of families	
Lack of communal pastures with water ponds collecting overflowing rainwater, where to bring cattle, goats and sheep to graze and drink without much damage to the environment's topsoil and vegetation (Carriacou).	Lack of attention to local livelihoods	
Persistent and sometimes violent conflicts between crop and vegetable farmers and 'Leggo' cattle/grazers owners (Carriacou).	Unresolved local conflicts	
Limited opportunities for public participation in policy design (Brazil)	Limited public participation	**Lack of local opportunities to participate**
Limited recognition of community-based knowledge (Brazil)	Limited recognition of local knowledge	

		in policy design.
Limited integration of scientific expertise, such as hydrological modelling or GIS-based watershed planning, to inform site selection (Pakistan).	Lack of evidence-based NBS design	**Lack of connectivity between science and policy**
Misunderstanding from political agents about the scientific results achieved (Brazil)	Communication challenges between science and policy	
Political agenda overlapping with the scientific agenda. (Brazil)	Contradictory scientific and political agendas	
Limited monitoring and evaluation of NBS outcomes reduces ability to assess long-term effectiveness (Peru).	Weak monitoring and evaluation systems	
Lack of coordination with forestry, agriculture, and disaster management departments limits systemic impact. (Pakistan)	Lack of policy coordination	**Incoherent policies**
Weak coordination between upstream NBS implementation and downstream water users limits incentives and systemic impact (Peru)		
Absence of linkage between pond-building and formal economic development programs (e.g., livestock subsidies, local markets) to enhance long-term income. (Pakistan)	Siloed policies	
Political incompatibility between the regional and national governments, potentially nullifying work done by local community due to problems to implement new project (Brazil)	Incompatible policies	
No institutional mechanism exists to scale or replicate the model?? under a coherent provincial or national water policy. (Pakistan)	Lack of policy support to scaling NBS	**Inefficient governance**
Construction lacks standardised environmental safeguards (e.g., erosion control, zoning) in some areas which risks local degradation. (Pakistan)	Weak regulation	
Free-roaming livestock undermines ecosystem restoration efforts (Carriacou)	Misalignment between land use practices and NBS goals	
Limited public provision of water services reinforces unequal access to water (Carriacou)	Weak public service provision	
Public institutions continue to prioritize the construction of gravity-fed irrigation canals and the establishment of nurseries for seedling production and distribution, without any accompanying short- or long-term development strategy (Peru).	Poor water management	**Poor water management**
Lack of paving and adequate drainage system, erosion, flooding and torrents. (Brazil)	Poor water management	

Short-term public funding model lack of long-term commitment for funding community-based NBS (Brazil)	Not enough long-term funding for community based NBS	**Limited funding for community-based NBS**
Peasant communities clearly recognize the need to protect forests and springs; they have available labor but lack the financial support for implementing pilot NBS or maintain them (Peru).	Lack of financial support for implementing pilot NBS or maintain them	
Reliance on externally funded NGO projects limits long-term continuity of NBS interventions (Carriacou)	Dependence on project-based funding	
Local authorities exhibited weak governance resulting in a loss of peasant communities' trust and don't rely on their management instruments or tools. (Peru)	Lack of local authorities' leadership	**Local Capacity, Leadership, and Awareness**
Private companies or agricultural exporters rely on short-term thinking and have limited understanding of the benefits offered by Water Sowing and Harvesting (WSH) projects (Peru).	Lack of local awareness on benefits of NBS	

Attributes of fit across the cases

The case reports identified set of good practices observed when implementing NBS on the ground. These good practices can be framed as attributes of fit. Case findings were clustered under nine general categories: 1) Integration of plural knowledges, 2) Community-based governance, 3) Inclusive governance, 4) Incentives for NBS, 5) Communication with local communities, 6) Holistic water management, 7) Ecological appropriateness, 8) Monitoring NBS, and 9) Support for local livelihoods. The nine general categories were built from the findings and insights given below (Table 4).

Notably, fit should be understood as dynamic rather than as a condition achieved once during NBS design or implementation. Ecological conditions, institutional arrangements, livelihood priorities, available capacities and societal acceptance may change over time, potentially transforming an initial fit into a misfit or vice versa. NBS therefore require mechanisms for monitoring, learning and adaptation that allow ecological interventions to remain responsive to changing socio-political contexts. Societal acceptance is particularly important in this regard because communities and other actors may reassess the legitimacy, costs and benefits of NBS as their effects become visible over time.

Table 4. Attributes of fit based on inductive content analysis of the case study reports

Insights from cases	Subcategories	General categories
The project combined scientific research on river hydrology and agroecology with the traditional knowledge held by smallholder farmers. Through participatory mapping, field experimentation, and community workshops, a two-way learning process was established. (Brazil)	Participation and co-creation	**Integration of plural knowledges** (How interventions are understood and designed?)
Work was carried out in close collaboration with peasant communities in Ayacucho, where a women-led community association shared their ancestral knowledge and practices related to rainwater capture and harvesting at a binational level between Peru and Costa Rica. This traditional knowledge was adopted and complemented with scientific insights derived from additional consultancies and studies (Peru).		
Use of local knowledge to identify pond locations in natural runoff zones (Pakistan).		
Water ponds excavation, swales and natural water irrigation network management: Following the advice and indications of older knowledgeable citizens, we identified two centuries-old, dried over silted ponds in overgrown forest sites, which were in use to wet crops plantations all around. (Carriacou)	Integration of local and experiential knowledge	
Long-term integration of intergenerational local knowledge and practice-based ecological understanding in NBS design (Carriacou)		
Peasant communities possess extensive knowledge and a strong willingness to conserve their ecosystems, which has facilitated positive relationships and collaborative agreements for joint work with them (Peru).		
Community participation throughout planning, implementation and monitoring strengthened local ownership and responsiveness of NBS interventions. Mutual knowledge exchange not only enhanced the technical efficacy of the interventions but also increased legitimacy and ownership among local actors. (Brazil)	Community participation throughout NBS co-creation cycle	
Strong example of participatory governance; community members manage implementation and monitoring. (Pakistan)		
Low level of bureaucracy means swift development of pond building and incentive dissemination. (Pakistan)	Adaptive and community-	

The low-tech, locally maintainable solutions included agroforestry systems, natural barriers, riverbank stabilization measures, and rain gardens integrated into existing settlement patterns. (Brazil)	based governance	**Community-based governance** (How decision-making is organized?)
NGO–community collaboration enabling locally embedded and adaptive implementation of NBS. (Carriacou)	Polycentric governance	
Integration of NBS within national legal and policy frameworks for water and environmental management. (Peru)		
The initiative relied on a multi-actor governance arrangement linking universities, NGOs, local communities, and land-regularization processes, enabling shared learning and adaptive implementation. (Brazil)		
Locally led, adaptive, and decentralized approach that aligns with global rainwater harvesting best practices and principles of NBS. (Pakistan)		
All of our initiatives include components of capacity building and gender inclusion, promoting the active participation of both women and men. (Peru)	Gender inclusivity	**Inclusive governance** (Who is included and empowered?)
Targeted inclusion of women in NBS-related activities and local employment. (Carriacou)	Women participation	
Active involvement of youth and local community members in conservation and environmental education activities. (Carriacou)	Intergenerational inclusion	
Digital verification through online communication channels like WhatsApp allows fast scaling and trust-building. (Pakistan)	Digital communication	**Communication and awareness building** (How support and legitimacy are built?)
Awareness was raised among the local population regarding the positive chain of effects generated by the implementation of NBS practices. (Peru)	Community awareness	
Environmental education and awareness-raising through youth programs, activities and community engagement. (Carriacou)		
Improved soil productivity, diversified agricultural production, and enhanced livelihood resilience created tangible incentives for continued engagement with NBS. (Brazil)	Incentives to ensure community engagement	**Incentives for implementing and maintaining NBS** (Why and how actors engage
People interested in building a water-harvesting pond on their private lands receive a financial reward of PKR 6,000. This incentive, which encourages more participation, is covered through community funding which suggests local ownership, responsibility, and awareness. (Pakistan)		

Provision of paid eco-jobs (e.g. forest gardeners) creating direct economic incentives for local participation. (Carriacou)		and remain engaged?)
Pilot initiatives involving green infrastructure were successfully implemented through the construction of reservoirs. One of the most significant examples is the "La Esperanza" reservoir, where rainwater infiltration was enhanced to promote the emergence of springs in the lower part of the watershed. (Peru)	Watershed level water management	**Holistic water management** (How the intervention addresses social-ecological system dynamics?)
Ponds enhance groundwater recharge, reduce surface runoff, and are planned to be coupled with afforestation for ecosystem recovery. (Pakistan)	Coupling water management and environmental restoration	
Integrated approach linking forest restoration, water retention (ponds, swales), and soil regeneration. (Carriacou)		
The intervention was ecologically targeted at riparian zones with urgent restoration needs. Agroforestry systems were implemented where they were ecologically appropriate, leading to visible improvements in biodiversity, soil quality, and hydrological regulation. (Brazil)	Ecologically appropriate interventions	**Ecological appropriateness** (Whether the intervention matches local ecological conditions?)
Restoration of endemic vegetation, including evergreen and flowering tree saplings and red mangrove propagules. (Carriacou)	Planting endemic species	
Community participation in monitoring enabled ongoing observation of ecological restoration and adaptive management of interventions. (Brazil)	Community-based monitoring	**Community-based monitoring of NBS** (How learning and adaptation occur?)
Video-based verification enables community-led monitoring. (Pakistan)		
Community-based ecological monitoring through observation of biodiversity recovery and site conditions. (Carriacou)		
By supporting diversified livelihoods through agroforestry, the project provided tangible economic benefits such as improved soil productivity and crop yields. (Brazil)	Support for local livelihoods	**Support for local livelihoods** (Longer term outcomes and social sustainability)
Ponds have enabled the return of livestock, helping families rebuild livelihoods and reduce poverty. (Pakistan)		
Support for local livelihoods through eco-employment and indirect benefits (e.g. ecotourism potential). (Carriacou)		

Recommendations to enhance the fit

In Figure 1, we synthetize results from Tables 3 and 4 and propose seven recommendations by which fit between NBS and local contexts ca be enhanced. To do so, we integrate the findings on signs of misfits and attributes of fit. Figure 1 shows the integration logic that leads to seven recommendations. The recommendations connect with social justice and local livelihoods, knowledge integration, holistic water management approaches, local capacities to implement and maintain NBS, ecological appropriateness of NBS and multi-level governance coordination and collaboration.

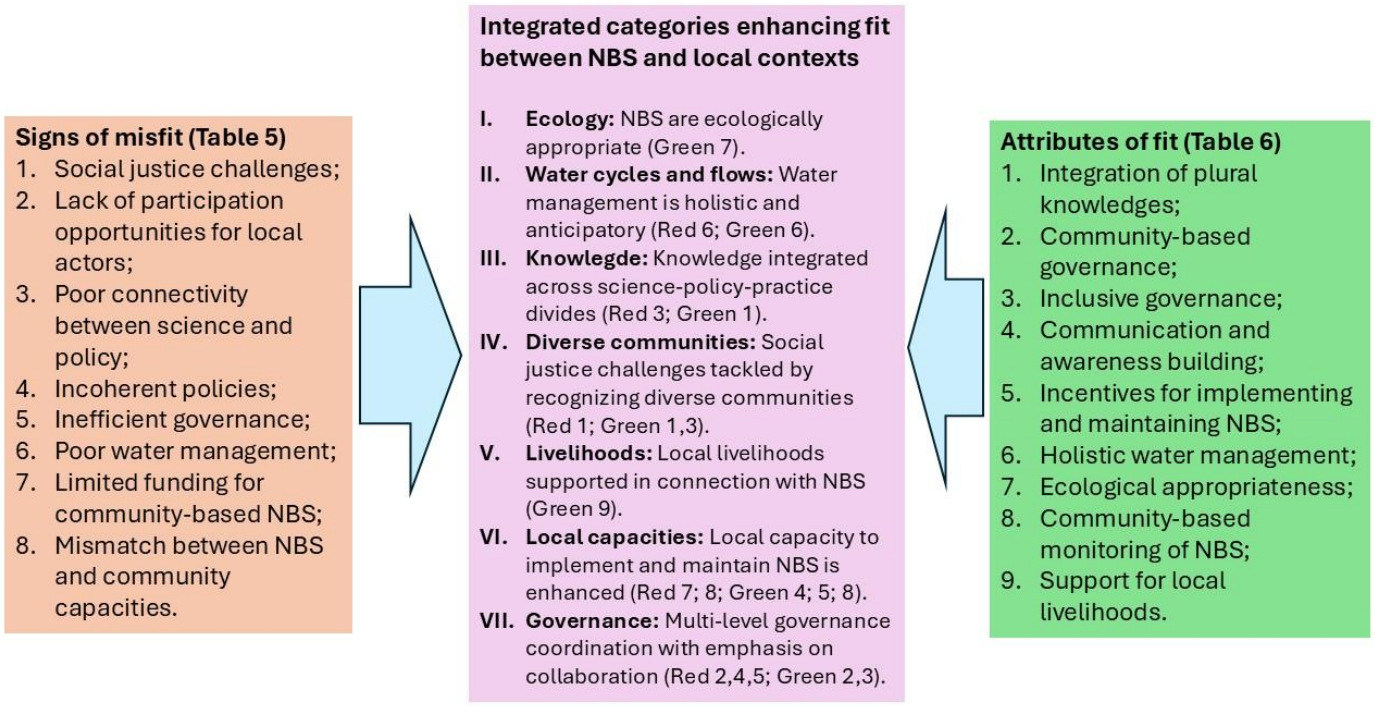


Figure 1. Basis for seven recommendations to enhance fit between NBS and local contexts.

Recommendation 1: Ensure ecologically appropriate nature-based solutions

Sometimes, if NBS are planned for specific purposes, they may encounter backlashes for biodiversity due to the use of non-native species as part of the NBS intervention (Brundu *et al.*, 2020; Jambhekar *et al.*, 2026). Ecological appropriateness was illustrated in the Brazilian case, where agroforestry systems were implemented when they were ecologically

appropriate, leading to visible improvements in biodiversity, soil quality, and hydrological regulation. In Carriacou, planting of endemic species was emphasized. In Brazil, riparian restoration, agroforestry systems, and rain gardens were designed to simultaneously enhance biodiversity, improve water retention, and strengthen hydrological regulation, illustrating the multifunctionality of ecologically appropriate NBS. The ecological appropriateness of NBS is of crucial importance to avoid future surprises and to match the NBS to local ecosystems instead of engineering solutions that may look good on paper, but that can compromise NBS in the future.

Recommendation 2: Establish a holistic and anticipatory water management approach

Water quality and quantity are affected by set of societal sectors and hence adaptive approaches are needed for water management (MacAlister and Subramanyam, 2018). The Peruvian case highlights a holistic approach to water management by recognizing water issues across a watershed, and not only in site-specific way. In Pakistan, the coupling of water management and reforestation efforts illustrate a holistic approach, too. In Carriacou, forest restoration, water retention (ponds, swales), and soil regeneration were integrated and formed an ecosystem-based, holistic water management approach. Adaptive approaches in the cases were also based on monitoring of water flows, such as in Brazil, where riparian restoration and rain gardens were designed to slow runoff, enhance infiltration, and contribute to broader hydrological recovery. Hence, water linked NBS can be compromised without holistic and anticipatory approach to water management, which is not bound to single sector, and not to isolated sites as the spatiality of water is connected to the water cycles and flows.

Recommendation 3: Use knowledge co-production to bridge science, policy, and society

To counter problems of technocratic NBS implementation, co-creation aspects have been emphasized, where local people engage in co-design, co-implementation and active maintenance of NBS (Soini *et al.*, 2023). All our cases verify the need to recognize plural knowledge across science-policy-society divides to enhance longevity of NBS. Transdisciplinary approaches combining scientific expertise with local perspectives were emphasized in Peru. In Brazil, participatory mapping of water systems, community workshops, and joint planning processes created opportunities for continuous knowledge exchange between communities, practitioners, and researchers. Importance of use of local knowledge for example to identify suitable pond locations when designing and

implementing NBS was stressed in the Pakistan and Carriacou cases. On the other hand, limited integration of scientific expertise, such as hydrological modelling or GIS-based watershed planning, to inform site selection was considered as a barrier for NBS implementation in Pakistan. Hence, to fit to local contexts NBS require the integration of scientific expertise and local knowledge. Policy makers' involvement in decision making enabling NBS is needed. Incoherent policies, in contrast, may hinder an effective implementation of NBS, as highlighted in all cases.

Recommendation 4: Recognize diverse members of the local communities for just outcomes

NBS aim to benefit people and nature, but they often face social justice challenges, and are frequently embedded in speculative elite-based development paths (Anguelovski and Corbera, 2023). The key question is who benefits and whose justice counts in relation to NBS (Bauer, 2023). Unresolved local conflicts and compromised access to water are also crucial social justice issues in these cases. If NBS cannot account for these issues, their maintenance and longevity are likely to face significant challenges. Our results highlight that communities affected by NBS are diverse. Participatory NBS co-design in Carriacou recognizes youth and women as particular stakeholder types, while Peru also addresses gender issues. Hence, NBS must take social justice issues and intergenerational participation seriously and develop means to rectify existing inequalities to avoid a situation where the inequalities are rather reinforced or even exacerbated through the implementation of NBS.

Recommendation 5: Ensure co-benefits among local livelihoods and nature values

Traditional nature conservation often excludes people and their livelihoods from protected areas (Bontempi *et al.*, 2023), and NBS can reduce local income opportunities through nature-based livelihoods. For example, restrictions on forestry or the establishment of new wetlands may reduce local income (Sarkki *et al.*, 2024). The Brazil case highlighted that diversifying local livelihoods through agroforestry, diversified production, and improved environmental conditions provided tangible economic benefits for the local community. The Pakistan case stressed that created ponds used for water management enabled livestock to return and help build local livelihoods and reduce poverty. Financial incentives for implementing and maintaining NBS were also important in Pakistan. In Carriacou, paid eco-jobs (e.g. forest gardeners) created direct economic incentives for local participation.

Hence, NBS need to recognize and support local livelihoods to mitigate conflicts, smoothen trade-offs, and to enhance co-benefits. Creating economic incentives and livelihood linkages to embed NBS into local development agendas can help improve fit.

Recommendation 6: Enhance local capacities to implement and maintain nature-based solutions

Experts outside should not design and implement NBS but this should happen with local actors (Sarkki *et al.*, 2025). In order to engage local actors with NBS co-design, co-implementation, and co-monitoring, certain knowledge and capacities are needed (see Cabling *et al.*, 2024; McEvoy *et al.*, 2024). First step is to establish effective communication channels between various actors who influence and are affected by NBS (Pakistan). NBS may be perceived as an "unusual" approach, and hence awareness raising on the benefits of NBS for local communities and stakeholders is often needed, as illustrated by the Peruvian case. In Carriacou, a combination of environmental education, awareness-raising through youth programs, and integration of intergenerational local knowledge and practice-based ecological understanding was noted. Furthermore, monitoring the benefits and effects of NBS after implementation can raise awareness of their benefits, and also point to opportunities for local engagement in long-term maintenance of NBS, as highlighted in Brazil and Pakistan cases. In Brazil, low-tech, locally manageable interventions such as agroforestry systems, natural barriers, and rain gardens also enhanced local capacities for long-term maintenance and stewardship. In sum, NBS should not be understood as one-shot interventions which are designed and implemented without active maintenance. Local people can play crucial roles in this maintenance, so it is important to plan the NBS so that local people have incentives and capacities to maintain them.

Recommendation 7: Build NBS on multi-level coordination and collaboration

NBS are not just environmental interventions. They require governance solutions that transcend dominant techno-market interventions by ensuring meaningful local participation and avoiding the perpetuation of unequal power relations to prevent "democracy washing" (Hafferty *et al.*, 2025). Our cases stressed the importance of community-led governance approaches that enhanced local ownership of NBS through approaches that advance environmental stewardship (Peru & Brazil). NBS including adaptive and collaborative management were emphasized in Pakistan. The Brazilian case further demonstrated the importance of multi-actor governance arrangements linking universities, NGOs, local communities, and land-regularization initiatives, enabling shared learning and

adaptive implementation. NGO-community collaboration enabled locally embedded and adaptive implementation of NBS in Carriacou. Novel and collaborative governance approaches are also needed to move forward from inefficient governance and incoherent policies challenging implementation and longevity of NBS in Pakistan. In sum, collaborative governance approaches that capitalize on local engagement also need to connect to wider-level policies to ensure resources for NBS and decision-making that is robust yet flexible to local conditions to ensure the longevity of NBS (See Figure 2).

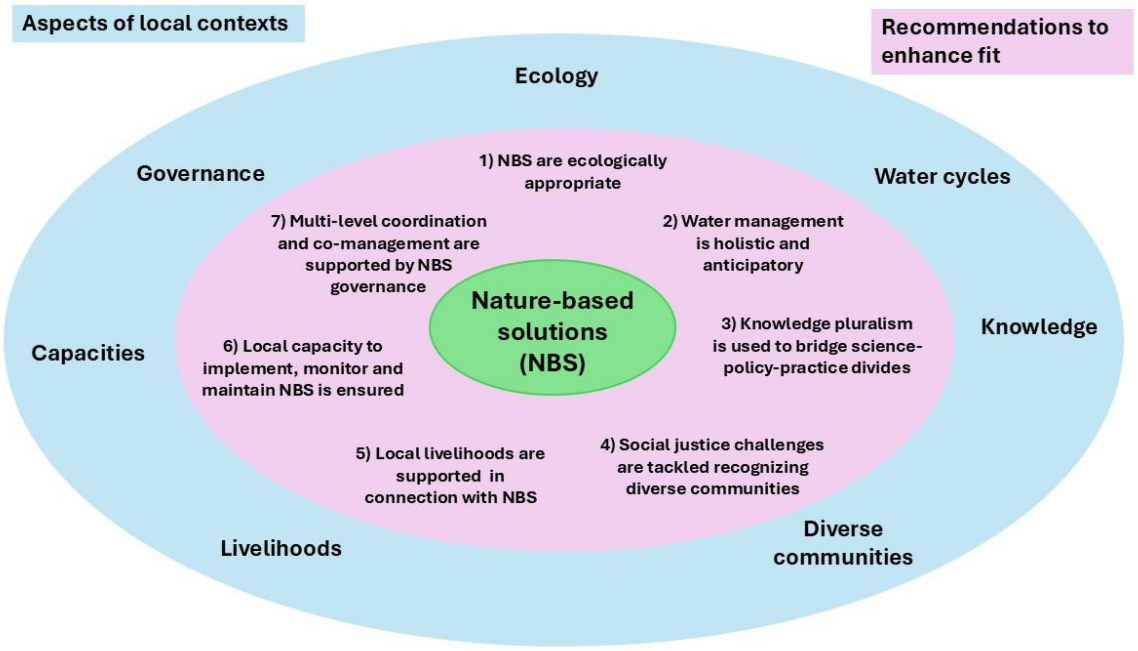


Figure 2. Seven recommendations to enhance fit between NBS and local contexts.

Discussion

This paper applied the concept of fit to analyze linkages between water-related NBS and local contexts across four Global South contexts – Brazil, Pakistan, Peru, and Carriacou / Grenada. Though inductive qualitative content analysis, we identified seven recommendations to enhance fit between NBS and local contexts.

Our starting point was the assumption that NBS must fit local contexts to enhance their long-term sustenance, to catalyze co-benefits with local communities, and to plan NBS in ways that recognize local ecological conditions. Local contexts can be an empty word without specification. Our multidimensional fit approach began by separating contextual

aspects, including governance, economy, knowledge, environment and technology (Table 1). These contextual aspects are general and not specifically developed for analyzing NBS. Hence, we conducted inductive qualitative content analysis and identified seven key aspects of local contexts relevant for NBS: 1) ecology, 2) knowledge, 3) governance, 4) diverse local communities, 5) local livelihoods, 6) community capacities to implement and maintain NBS, and 7) water cycles and flows (Figure 2). The first three aligned with our starting point on five dimensions of fit. Local livelihoods link to economic aspects of fit (Biggs, Schlüter and Schoon, 2015), but we specify that NBS must comply with and support local livelihoods. Community capacities connect to technological fit (van der Hel, 2016), and here we connect them to accessibility tools for monitoring NBS impacts, but also to a wider set of skills required to implement and maintain NBS over the long term. We further emphasize the need consider socio-cultural fit (Sarkki, Rantala and Karjalainen, 2015) not as a simple, singular, all-encompassing construct, but rather as something to diagnose in relation to the diverse actors who constitute local communities, including different genders and age groups. Finally, understanding water cycles and flows is critical and in all our cases local knowledge informed water-related NBS. These seven aspects of local contexts provide a fertile departure for subsequent assessments of fit between NBS and local contexts.

We also identified seven recommendations linked to the seven aspects of local contexts to enhance fit (Figure 2). We classify the seven recommendations further under three types of conditions that provide opportunities for enhancing fit between NBS initiatives and local contexts. Concept of enabling conditions has been used for example in context of Payments for Ecosystem Services (Huber-Stearns *et al.*, 2017). We consider conditions that are connected to NBS design, implementation and governance. The three types of conditions add value to the recommendations by identifying key domains for NBS developers to further enhance fit. NBS design here refers to the process where NBS are planned and co-created (Lupp *et al.*, 2021). Critical design conditions are connected to our recommendations 1–5. However, NBS design matters only if NBS are implemented in practice. NBS implementation refers to changes in physical environments and maintaining those changes over time (see Sarabi *et al.*, 2019). Implementation conditions that enable fit connect to our recommendations 1, 2, 4, 5 and 6. Governance conditions are also important for both design and implementation of NBS. Collaborative governance arrangements help NBS endure over time (Battisti, Cuomo and Manganelli, 2025), and refer to processes in which actors exercise decision authority, resource control, and stewardship responsibility on NBS (Enu, Albert and Jessel, 2026). Enabling governance conditions are covered by our recommendation 7 (Figure 3).

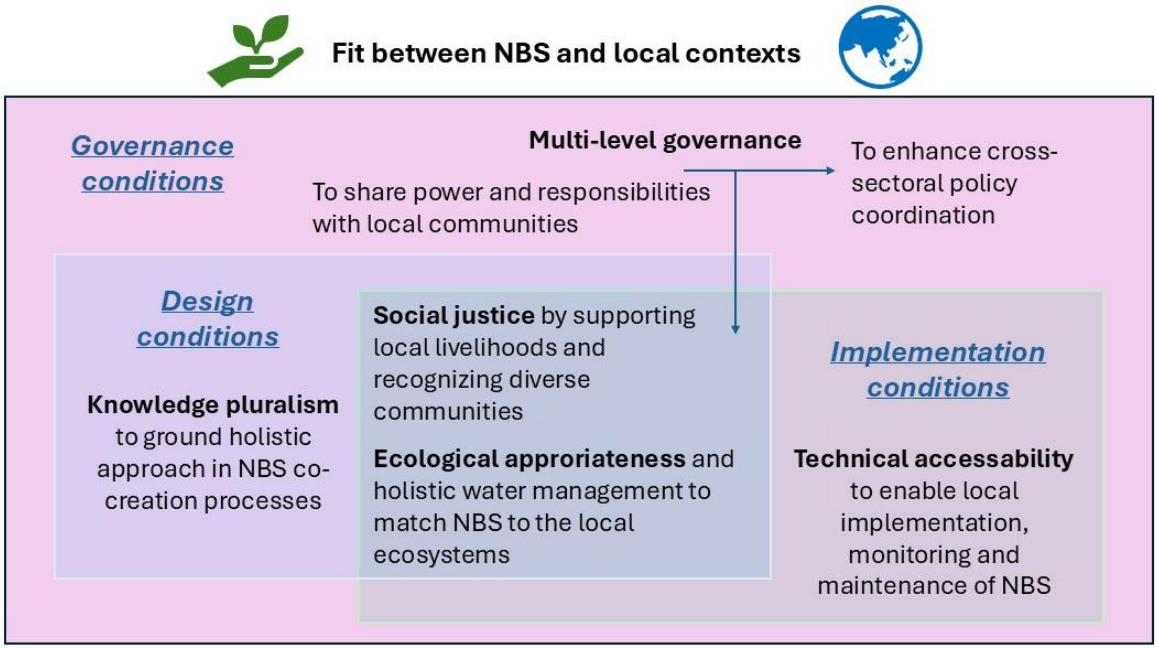


Figure 3. Design, implementation and governance conditions that enhance fit between NBS and local contexts.

Our analysis shows that the fit of NBS depends not only on their ecological design, or not even on their co-creation alone, but also, crucially, on how they engage with and link to broader socio-environmental contexts and needs. We proved the value of fit concept in analyzing NBS and developing holistic view on how NBS can be molded into the contexts where they are designed, implemented and governed. NBS literature often focuses on co-creation and co-design aspects (e.g., Lupp *et al.*, 2021), match between NBS and local ecologies (e.g., Buckley *et al.*, 2024), or NBS governance (e.g., Enu, Albert and Jessel, 2026). Our paper highlights that these approaches must be combined to gain a holistic view on the NBS to enhance fit among NBS and local contexts. Co-creation without power sharing, or attention to local ecologies and support for local livelihoods, compromises the social justice of NBS. Ecologically aware NBS design that relies on science may neglect local knowledge and governance aspects crucial for longevity of NBS. Finally, NBS governance alone cannot do much without careful co-design of NBS at the level of practical solutions and management approaches to implement and maintain them.

Finally, our paper urges future research to deepen theoretical understanding of fit dynamics, develop context-sensitive evaluation frameworks, and explore how NBS can catalyze long-term transformations toward sustainable and just water governance. As global interest in NBS grows, this paper serves as a timely reminder that effective and

equitable nature-based solutions cannot be transplanted wholesale. They must be grown locally, nurtured and supported by wider and inclusive governance approaches, and continually adapted through feedback and collaboration. Only by embracing this grounded, evolving approach to *fit* can we unlock the full potential of NBS for resilient and inclusive water governance in the Global South and beyond.

Methods

Research materials

The research materials on the four cases are based on varying mixed method approaches (Table 3).

Table 3. Types of materials across the four case studies.

Types of materials	Brazil	Carriacou	Pakistan	Peru
Direct engagement in the NBS initiatives	Yes	Yes (long-term engagement since 1990s through implementation of conservation and restoration projects)	No	Yes (3 years)
Participant observation	Yes (2 years), embedded within a longer-term engagement with the territory since 2016 through a Right to the City approach.	Yes (long-term embedded observation through residence and project implementation since 1990s)	Yes (2-3 months)	Yes (at multiple stages; at the beginning of the project, during implementation and at the end)
Participatory workshops	Yes (2 years) within the Living Periphery Programme (*Ministério das Cidades)*	Yes (multiple workshops involving community participation across diverse age groups, including youth)	Yes (2 workshops)	Yes (45 workshops)

Interviews	Ongoing conversations and deliberation with community members through the Management Committee.	Yes (expert interviews with local professionals and knowledge holders)	Yes (7 Interviews) with whom, what were the themes?	Yes (more than 6 Interviews with representatives from public institutions, private sector, CSOs, and local communities)
Policy document analysis	Yes	Not available	Not available	Yes, the project was developed under the legal framework of Perú, which includes the Water Resources Act No. 29338, the General Environmental Law and the Forestry Law
Review of grey literature	Yes, review of local drainage policies.	Yes (sources including reports, media articles, and project documentation)	Yes (10-15 documents including op-eds, newspaper articles, documentaries, and reports)	Yes, almost 10 different documents reviewed by the team related to the Economic Ecological Zoning (EEZ), Guide to the economic valuation of natural heritage, Ecosystem Services, and another plans or memories of other projects related.
Surveys and questionnaires	Yes, applied during the initial phase of the urbanism Project of the territory.	Yes, physical and drone survey of the restoration area, including tree/plant species and biodiversity	Yes (1 questionnaire with 20 respondents)	Yes, particularly to identify the stakeholders (Public, private, CSO and population)
Other	Aerial surveying and aerial photogrammetry using drones.	Ecological monitoring, practice-based knowledge, and community/citizen science activities	Fieldwork analysis combined with desk-based evaluations	Technical studies (zoning, ecosystem services), and combined desk-based and fieldwork analysis

To ensure comparability of the cases, the case study authors were asked to provide a report on their cases following common instructions and framework. The instructions included brief explanation of the fit-based framework, and sections on 1) introduction of the case study area, 2) material and methods used to have insights on the case studies, 3) missed opportunities / misfits, 4) seized opportunities / fits, and 5) lessons learned (Annex 3 for details). The instructions also included fit-based examples on fits and misfits connected to the five dimensions in our framework (see Table 1), which were used to inform analysis of missed and seized opportunities. Based on the instructions, each case study author provided a 3–5-page case study report.

Analysis of the case studies

We employ the exploratory multiple case-study approach to investigate how the concept of fit can explain the successes and limitations of water linked NBS initiatives across diverse Global South contexts. Multiple case-study analyses are particularly suitable for analyzing complex, context-dependent phenomena like environmental governance, where institutional dynamics, cultural practices, and ecological processes interact in non-linear ways (George and Bennett, 2005; Yin, 2018).

Our analysis followed a qualitative content analysis process, where we started with deductive approach, but then moving to inductive approach to develop novel conceptual insights (Elo and Kyngäs, 2008) on NBS and fit in Global South. The deductive start was needed to frame the case studies to allow the explorative comparative analysis of the case studies. The instructions for the case study authors ensured sufficient similarity in the materials to allow cross-case analysis. Our deductive approach derived from a fit–misfit diagnostic framework, propounded by Young (2002), and further adapted by Folke *et al.*, (2007), Epstein *et al.*, (2015), and Pahl-Wostl *et al.*, (2023).

Qualitative evidence was extracted from the case study reports and categorized as representing either a fit (seized opportunity) or a misfit (missed opportunity). The specific findings under these general themes were inductively clustered, resulting in the key categories that reflected the fit and the misfit. These categories were then merged to identify recommendations to enhance fit between NBS and local contexts. The recommendations are especially relevant for water-related cases in Global South. However, these recommendations are likely applicable beyond the case studies and diverse Global South contexts.

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